

Lake Davis Northern Pike Eradication Options

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1.0. Introduction

This preliminary evaluation by the Department of Fish and Game (Department) outlines options which, alone or in combination, might eradicate the invasive northern pike (*Esox lucius*) infesting Lake Davis. We examine the options in terms of criteria developed by the Department and the Lake Davis Steering Committee: (1) effectiveness, (2) feasibility, (3) registration for use in California, (4) human health and safety, and (5) ecological safety. This evaluation indicates that the use of formulated rotenone or a combination of formulated rotenone and rotenone powder combined with a significant drawdown of Lake Davis could be a feasible, effective and safe method for eradicating the pike at Lake Davis. However, the specifics of this combination require substantial development and stakeholder involvement before an actual project can be proposed and evaluated under applicable environmental laws.

Lake Davis was chemically treated for northern pike in October 1997, which were rediscovered in May 1999. Since February 2000, the Department has been implementing a “control and containment” adaptive management strategy jointly developed by it and the Lake Davis Steering Committee. During implementation of the “control and containment” strategy, which is based on mechanical removal using nets and electrofishing, nearly 40,000 pike have been removed from Lake Davis. Although these ongoing control actions may have slowed the growth of the northern pike population, they did not prevent dramatic population growth during the first three years of implementation. This may be because pike often grow more rapidly, mature earlier, and have higher fecundity when densities are low.¹

In December 2003, recognizing that the threat to the Lake Davis trout fishery and the potential for the natural or human movement of pike to other waters is not diminishing, the Lake Davis Steering Committee requested that the Department consider the options for ridding Lake Davis of northern pike. The Steering Committee requested that this be done in cooperation with local, state and federal agencies and the community, in a way that would protect public and environmental health, as well as lessen any negative impacts to the local economy. California Resources Secretary Mike Chrisman concurred that it is imperative that the Department determine a safe and effective way to rid northern pike from the state.

2.0. Control Efforts

There are a variety of options for dealing with an introduced species that will spread and cause problems on a large scale. If eradication is not feasible, management of the organism by controlling its population and attempting to slow or halt its geographic spread may be the only other option. After the 1997 treatment of Lake Davis and the reappearance of pike in 1999, the community

¹The increase in the Lake Davis pike population from 1999 levels is detailed in summary report, available from the Department’s Portola office (address on the front of this report) or from the web at: www.dfg.ca.gov/northernpike/summary_report.

and the Department developed a plan to control pike numbers and keep them contained within the reservoir.

Under *Managing Northern Pike: A Plan for Y2000*, the Department and the local community identified recommendations for keeping the northern pike population at Lake Davis contained and controlled. Under this plan, various removal methods, such as the use of nets and electrofishing, were combined with improved public education and outreach. The California Department of Water Resources altered its reservoir management criteria to reduce the chance of an uncontrolled spill, and a grater was installed at the outlet structure at the base of the dam to reduce chances of pike leaving Lake Davis. Law enforcement and public education were improved to reduce the chances of humans moving pike to other locations.

Implementation of this plan was evaluated in 2003 in *Managing Northern Pike at Lake Davis, A Plan for Year 2000: Three Year Report* (see http://www.dfg.ca.gov/northernpike/summary_report.pdf). During four years of implementation, nearly 40,000 pike have been removed from Lake Davis by mechanical means. The vast majority of these fish were small “young-of-the-year” less than ten inches long. The catch rate data indicate that the pike population grew tremendously during the first three years of implementation, but may have grown more slowly or leveled off in year four. Angler survey and monitoring data indicated that trout densities in Lake Davis have decreased. This may have been partly due to pike predation but was also likely a reflection of a decrease in annual stocking numbers beginning in 2000 after an unusually large stocking program in 1998 and 1999. Catch rate data suggests the density of larger pike capable of eating catchable-size trout may have remained about the same or increased more slowly than the pike population as a whole. The containment program is also at risk. Increased pike abundance increases the likelihood of pike escaping the reservoir. Although both education and enforcement activities may have reduced the risk of human movement of pike, increases in pike density (and the potential to catch and move pike) may have cancelled out these effects.

3.0. Eradicating Pike

The two best-known and proven methods for eradicating an unwanted fish species are complete dewatering or the use of a fish poison (piscicide). The alteration of habitat has been known to cause specific species of fish to go extinct, as has over-harvesting and introduction of new species. These facts have led to suggestions to alter the Lake Davis habitat on a lake wide scale (such as mechanically removing aquatic vegetation), ramping up current pike removal methods such as nets and electrofishing, and introducing another predator fish. Another suggestion has been to drop reservoir levels during the spring spawn.

Aspects of the life history of pike combined with the environmental conditions in Lake Davis, however, strongly suggest that these ideas would not

result in eradication. Indeed, implementation of the pike plan has demonstrated that large-scale removal may have slowed the growth of the pike population, but even after the removal of nearly 40,000 pike, they are still numerous. Some of the reasons for this may include the fact that lowering the numbers of pike in an area can result in more rapid growth rates, earlier maturation and more eggs. In addition, a large area of Lake Davis is relatively shallow and covered with thick aquatic vegetation, creating widespread and ideal spawning habitat. If spawning is halted or discouraged in one area, there are many other places where the pike can spawn successfully.

3.1. Development of Evaluation Criteria

The Department and the Lake Davis Steering Committee articulated several considerations regarding the eradication options. The health and safety of the public and workers was deemed critical. Recommended options must have demonstrated effectiveness in the laboratory and in the field. Options must meet all legal requirements. Lastly, the options must be as safe for the environment as reasonably possible, including being as highly selective as possible and breaking down rapidly in the environment. These considerations can be expressed as the following criteria: (1) Regulatory Compliance; (2) Feasibility; (3) Effectiveness; (4) Human Health and Safety; (5) Ecological Impact.

3.1.1. Permitted for Use as a Piscicide

The first criterion is whether or not the particular option is legally permitted in California. Manufacturers must register piscicides with the United States Environmental Protection Agency (USEPA) and the California Department of Pesticide Regulation (CDPR) before anyone can buy or use them in California. This process is designed to protect both people and the environment. The manufacturer must supply information on: exposure risks and how to protect people, pesticide residues, any hazards that the inert ingredients may pose, what effect any volatile organic compounds could have on air quality, and other data as requested such as toxicity to plants or impurities in the product.

3.1.2. Feasibility

The second criterion is whether or not implementation of the particular option is feasible. This addresses the technical aspects of the option in the context of how it would work in the physical and biological environment of Lake Davis, as well as its readiness for implementation and the ability of the Department to implement it.

3.1.3. Effectiveness

The third criterion is whether or not implementation of the particular option will be effective, which considers both the potential benefit an option might provide (i.e. eradication of the pike) and the probability that this benefit will be actualized as proposed. Effectiveness is evaluated in terms of demonstrated

success in the field and in the laboratory. Only options with a good track record of success will meet this criterion.

3.1.4. Human Health and Safety

Any option that is ultimately chosen should be safe for onsite workers as well as the general public. Two of the eradication agents (powdered rotenone and liquid formulated rotenone, such as Prenfish®) are registered for use in killing fish with both the United States Environmental Protection Agency (USEPA) and the California Department of Pesticide Regulation (CDPR). As such, they have undergone lengthy assessment of exposure risks, analysis of residues and biodegradation, any hazards that the inert ingredients may pose, and what effect any volatile organic compounds could have on air quality. They both have explicit directions for use on the label designed to protect human health and safety. Eradication agents which have not been analyzed by and registered with the USEPA and CDPR have not undergone an equal level of scrutiny in regards to human health and safety issues related to their use as a fish-killing agent.

3.1.5. Ecological Impact

Any pike eradication project will have ecological impacts. Any option that is ultimately chosen must be as safe for the environment as reasonably possible. Environmental effect should be as short-term as possible. The optimum eradication agent would be highly selective and have low persistence in the environment.

3.2 Water Level Scenarios

In order to determine the size and timeframe of possible projects, we examined five different water level scenarios, including complete dewatering (Table 1). Important considerations in evaluating different water levels are:

- Size of the remaining pool
- Resulting length of stream channel potentially containing pike
- Ensuring pike eggs and larvae are not discharged in the outflow
- Predicted time to draw down
- Predicted time to refill

This evaluation looks at the first two considerations (size of remaining pool and estimated length of stream channel). A more thorough examination of these considerations, particularly methods for ensuring that eggs and larvae are not discharged, and the predicted times for draw down and refill would need to be undertaken before an option is proposed for implementation. Before a project is ultimately chosen, hydrologists should examine each of the water level scenarios (both draw down and refill) in greater detail in terms of how long it would have taken to achieve each of the scenarios in the historical record of years since inflows to Lake Davis have been recorded or estimated. The lower the water level scenario, the greater the risk that it will take longer than one year to achieve

the desired goal. Some scenarios may take two, three or four years depending upon inflows. Likewise, the lower water-level scenarios run a higher risk of taking more than one season to refill the reservoir back to a usable level.

Table 1. Water Level Scenarios

Scenario	<i>Elevation</i> <i>(feet above sea level)</i>	<i>Approx. Surface area</i> <i>(acres)</i>	<i>Approx. Volume</i> <i>(acre-feet)</i>	<i>Approx. Length of Streams¹</i> <i>(miles)</i>
1. Empty	5,670 (elevation of streambed at dam site)	0	0	17-22
2. Minimum pool	5,700	25	90	17-22
3. Nearly empty (6% capacity)	5,738	550	5,000	14-19
4. One-quarter full (25% capacity)	5,752	1,600	20,000	13-18
5. Two-thirds full (66% capacity – typical summertime level)	5,767	3,200	55,000	10-15

¹Surface area and volumes based on California Department of Water Resources Lake Davis area-capacity tables. Stream length is estimated from maps and will depend on flows and headwater locations in year when project is implemented.

3.2.1 Complete Draining (Water Level Scenario 1)

This scenario envisions the complete dewatering of Lake Davis without the use of an additional agent, such as the fish poison (piscicide) rotenone. Lake Davis was formed by a dam on Big Grizzly Creek, which provides year-round inflow into the reservoir. If Lake Davis were completely dewatered, Big Grizzly Creek and its Cow Creek, Freeman Creek and Oldhouse Creek tributaries would continue to flow. These creeks are spring-fed from many different locations along their length, so it would not be possible to divert their flow at the headwaters. A complete dewatering project would need to address eradication of pike remaining in the several miles of these creeks. In addition, the lowest valve in Grizzly Dam will leave a small pool (about 25 surface acres) above the dam. A method would have to be developed to remove the remaining 90 acre-feet of water (about 29 million gallons).

3.2.2. Partial Draining (Water Level Scenarios 2-5)

Partial draining of Lake Davis is technically feasible and could be combined with an eradication agent to remove pike from the remaining waters. We estimated the time it would take to drain down the reservoir to various levels by looking at historical inflow (excluding evaporation) records for 1967 through 2003. We estimated that average release at Grizzly Dam while drawing down the reservoir would be 140 cubic feet per second (cfs). In reality, releases range

from only a few cfs to 230 cfs depending upon the reservoir elevation and outlet valves used. We did not estimate refill times – these will also depend on inflows. Before a project is ultimately proposed, the inflow data should be analyzed in detail.

Scenario 2 (Minimum pool – volume 90 acre-feet) envisions water drawn down to the bottom outlet valve. An pool of about 25 surface acres with a volume of about 90 acre-feet of water would remain above the dam. Assuming a January 1 reservoir volume of 50,000 acre-feet, we estimate it would be possible to draw the reservoir down to Scenario 2 by August 1 in at least one year out of three. If the January 1 reservoir volume was 60,000 acre-feet or greater, it would take two seasons or more.

Scenario 3 (Nearly empty – volume 5,000 acre-feet) envisions water drawn to 6% of the reservoir's capacity. Assuming a January 1 reservoir volume of 50,000 acre-feet, we estimate it would be possible to draw the reservoir down to Scenario 3 by August 1 in at least one year out of three. Assuming a January reservoir volume of 60,000 acre-feet, it would be possible to reach this level in about one year in five. Most of the time it would require two or three years to reach this level.

Scenario 4 (One-quarter full – volume 20,000 acre-feet) envisions the water drawn down to 25% of the reservoir's capacity. Assuming a January 1 reservoir volume of 50,000 acre-feet, the water could be drawn down to this level by August 1 in most years. If the January 1 water volume was 60,000 acre-feet, it would still be possible to draw down to this level by August 1 in one out of two years.

Scenario 5 (2/3 full – volume 55,000 acre-feet) is a drawdown to 66% of the reservoir capacity. If the January 1 water volume was 50,000 or 60,000 acre-feet, it would be possible to reach 55,000 acre-feet by August 1 in almost every year (there were 3 extremely wet years out of the last 37 in which high inflows may have prevented this). If the January 1 water volume was 80,000 acre-feet it would be possible to achieve 55,000 acre-feet by August 1 in about six out of ten years.

3.3 Eradication Agents

We examined nine agents that could be used to eradicate pike, and evaluate them according to the criteria described above.

3.3.1. Powdered Rotenone

The powdered form of the piscicide rotenone (produced from the roots of tropical legumes such as *Derris* spp. and *Lonchocarpus* spp.) is a proven and feasible method for eradicating fish in standing water. In areas where the source plants occur naturally, rotenone has been used historically to kill fish. In the United States, it has been used in fisheries management since the 1930s.

Powdered rotenone can have limited effectiveness in moving water such as streams and creeks. Registered for use as a piscicide with the USEPA and the CDPR, powdered rotenone has undergone extensive laboratory and field-testing and has explicit directions for use. If used according to label instructions, both the United States Environmental Protection Agency and the California Department of Pesticide Regulation have determined the product safe for workers and the general public. Powdered rotenone is extremely toxic to organisms that obtain oxygen through the gills. It readily biodegrades in water via oxidation and in light via photolysis.

3.3.2. Standard Formulated Rotenone (e.g. Prenfish®)

Standard liquid formulations of rotenone (for example, Prenfish®) are a proven and feasible method for eradicating fish in both standing and flowing water. Registered for use as a piscicide with the USEPA and the CDPR, the Prenfish formulation has undergone extensive laboratory and field-testing and has explicit directions for use. The formulation consists of rotenone extract dissolved into solvents and emulsifiers which help it mix into water.

According to the Prenfish® label, the product contains aromatic hydrocarbons as part of the solvent system. By definition, aromatic hydrocarbons are volatile and do not remain in water for long. These compounds, particularly naphthalene, have a strong odor, which was noticed during the 1997 treatment. Some people reported getting ill from the odor.

Some rotenone formulations use a smaller amount of rotenone with a pesticide synergist, piperonyl butoxide. The piperonyl butoxide is far less toxic than rotenone, but makes the rotenone more effective so that less rotenone is needed to get the same effect. When Lake Davis was treated with Nusyn-Noxfish® in 1997, this compound did not biodegrade as readily as the other compounds. It was detected at the part per billion level in the deepest sampling station in Lake Davis for about seven months following the October 1997 treatment.

With the exception of the synergist piperonyl butoxide, rotenone is the most persistent chemical in the standard liquid formulation. Rotenone itself readily decomposes in water (oxidation) and light (photolysis). Standard formulated rotenone may contain other ingredients which are proprietary information and therefore not listed on the label. All ingredients, however, were disclosed to the USEPA and CDPR and taken into consideration when the product was registered.

3.3.3. Formulated Rotenone (Finnish)

About 15 years of research and development have resulted in an alternative rotenone formulation that is currently being used in Europe. Its effectiveness has been demonstrated in laboratory and in the field. According to the scientists working on this formulation, the formulation uses diethylene glycol

ethyl ether, 1-methyl-2-pyrrolidone and a fatty acid ester to improve the rotenone's ability to dissolve into water. As with the traditional formulation of rotenone, the solvents and emulsifiers break down rapidly. The product has a faint odor. The Finnish formulation of rotenone is registered for use by the United States Environmental Protection Agency but is not yet registered by the California Department of Pesticide Regulation. During monitoring of field trials in the United States, rotenone was the most persistent chemical in the formulation.

3.3.4. Antimycin.

Antimycin (an antibiotic drug) has undergone extensive laboratory testing and field use as a piscicide, and is both a feasible and effective method to kill fish in flowing and standing waters. However, antimycin is not effective in deep lakes or in water with pH values greater than or equal to 8.5. Since the pH of Lake Davis can exceed 8.5, it is probably not appropriate for use in that environment. Antimycin is registered for use as a piscicide by the United States Environmental Protection Agency. However, antimycin is not currently registered with the California Department of Pesticide Regulation due to a lack of public and work health and safety data. Due to the expense of obtaining the required data, it is not anticipated that the product will be registered for use in California.

3.3.5. Copper sulfate.

Copper sulfate is very toxic to fish and a variety of other aquatic organisms, but does not have a history of use specifically as a piscicide and is not registered for use as a piscicide by the USEPA or the CDPR. In aquatic systems, copper sulfate has been used mainly as an algicide. We did not find any examples of copper sulfate being used specifically as a piscicide, nor any laboratory or field tests of its effectiveness. While it is very soluble in water, it does not volatilize. Instead, the copper tends to bind to sediments, and persists in the environment for extended periods.

3.3.6. Chlorine.

Chlorine (in the form of hypochlorite, the same agent used in laundry bleach) is highly toxic to fish at levels that are safe for humans. It has been used since the 1900s to disinfect drinking water and treat wastewater. When chlorine is added to water with organic content, hazardous byproducts such as trihalomethanes are produced. Chlorine generally dissipates from water in a few days. Chlorine kills fish, crustaceans, amphibians, reptiles, mollusks, gastropods, algae, plants and plankton. Chlorine has been used in fish eradication projects. It is not registered for use as a piscicide by USEPA or CDPR.

3.3.7. Chloramine.

Chloramine, which is caused by the reaction of chlorine and ammonia, has been used for drinking water treatment since the 1930s. Chloramine does not

result in the formation of as many trihalomethanes as chlorine but is persistent in water and requires removal with carbon-activated filters. We did not find any examples of chloramine being used as a piscicide. Chloramine kills fish, crustaceans, amphibians, reptiles, mollusks, gastropods, algae, plants and plankton. Chloramine is not registered for use as a piscicide in California.

3.3.8 Altering Water Quality Parameters

Introduction of large amounts of nutrients in the form of sugar and alcohol has also been suggested as a way to kill fish. Introduction of large amounts of nutrients dramatically increases the biological oxygen demand (BOD) of the water. Bacteria multiply rapidly to degrade the nutrients and deplete dissolved oxygen to levels that are lethal for fish. This method has been used at an abandoned mine pit in Wyoming to increase bacteria for the purpose of biodegrading uranium and selenium, but has not been laboratory- or field-tested for use as a tool for killing fish.

Another suggestion is to introduce large quantities of CO₂ under ice. High levels of CO₂ may raise water acidity, inhibiting pike growth and reproduction. More information would need to be obtained through research and laboratory and field studies.

Both of these methods lack adequate laboratory testing on their effectiveness and feasibility, lengthy field trials and a proven track record of successful use on a scale comparable to Lake Davis.

3.3.10 More Information

More information on each of the agents is on file at the Department field office in Portola (address on the front of this report). Please feel free to contact us at (530) 832-4067 if you have any questions or would like to examine the information we have on file. Also, copies of *Lake Davis Water Quality Group Handouts, March-August 2003* are available at our office, which contain information on rotenone and rotenone formulations.

3.4 Analysis of Options

The water-level scenarios and nine eradication agents are rated according to the five evaluation criteria (Table 2). Of the five water-level scenarios, only a complete draining would achieve the objective of pike eradication, and this option is not considered feasible. However, the other lake-level scenarios could be combined with an eradication agent.

Of the nine eradication agents, only the standard liquid rotenone formulation (e.g. Preenfish®) meets all of the criteria of being permitted for use in the United States and in California and having undergone the required human health and safety review; having a lengthy historical record of effective use, and being effective in both standing and flowing water. The agent is also selective to

gill-breathing organisms, does not harm plants and biodegrade readily in the environment. If the Finnish liquid rotenone formulation is approved for use in California, it would also meet these criteria. Powdered rotenone meets each of the criteria except for effectiveness in flowing water.

A liquid formulation of rotenone, or a combination of a liquid formulation and powdered rotenone could be used in combination with one of the lower water level scenarios in Lake Davis. One advantage of a lower water-level would be that a smaller quantity of the piscicide would be required for a successful project. Also, a smaller project would be easier to implement from a logistical standpoint.

Table 2. Eradication Options and Evaluation Criteria

- Evaluation Criteria -						
OPTION	Permitted for Use as a Piscicide	Feasible	Effective in Eradication	Human Health and Safety	Minimize Ecological Impacts	Notes
Water Level Scenarios:						
1. Complete Draining (no use of eradication agent)		O	X	X	see notes	Aquatic environment would be absent during project implementation
2. Minimum Pool		X	O	X	see notes	This scenario would be combined with eradication agent (see below)
3. Nearly Empty (6% capacity)		X	O	X	see notes	This scenario would be combined with eradication agent (see below)
4. Very Low (25% capacity)		X	O	X	see notes	This scenario would be combined with eradication agent (see below)
5. Low (66% capacity)		X	O	X	see notes	This scenario would be combined with eradication agent (see below)
Agents						
1. Powdered rotenone	X	X	O	X	see notes	Product meets U.S. Environmental Protection Agency human health and environmental standards if used according to label. May not be effective for fish eradication in flowing waters. Toxic to other fish and some invertebrate and amphibian life stages. Readily biodegrades.
2. Formulated rotenone (e.g. PreNFish®)	X	X	X	X	see notes	Product meets U.S. Environmental Protection Agency human health and environmental standards if used according to label. Toxic to other fish and some invertebrate and amphibian life stages. Readily biodegrades.
3. Formulated rotenone (Finnish)	O	X	X	N/I	see notes	Product meets U.S. Environmental Protection Agency human health and environmental standards if used according to label. Registration in California is pending. Toxic to other fish and some invertebrate and amphibian life stages. Readily biodegrades.
4. Antimycin	O	X	O	N/I	see notes	Product meets U.S. Environmental Protection Agency human health and environmental standards if used according to label. Not registered for use in California. Toxic to other fish and some invertebrate and amphibian life stages. Readily biodegrades.
5. Copper sulfate	O	N/I	X	N/I	see notes	Not registered for use in United States or California. Copper tends to remain in ecosystem. Toxic to most aquatic life including plants. Copper tends to remain in ecosystem, binding to sediments.
6. Chlorine	O	N/I	X	O	see notes	Not registered for use in U.S. or California. Chlorine dangerous to use; forms toxic trihalomethanes. Toxic to most aquatic life including plants.
7. Chloramine	O	N/I	N/I	O	see notes	Not registered for use in U.S. or California.
8. Addition of CO ₂	O	N/I	N/I	N/I	N/I	Inadequate laboratory and field-testing. No track record of successful use to kill fish on large scale.
9. Addition of Nutrients	O	N/I	N/I	N/I	N/I	Inadequate laboratory and field-testing. No track record of successful use to kill fish on large scale.

X = May meet criteria

O = Does not meet criteria

N/I = Need more information

4.0 Conclusions and Recommendations

The foregoing discussion suggests that the use of formulated rotenone or a combination of formulated rotenone and rotenone powder combined with a significant drawdown of Lake Davis could be a feasible, effective and safe method for eradicating the pike at Lake Davis. If a project is ultimately developed and proposed, it would be evaluated thoroughly under applicable environmental laws.

5.0 References

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